# Immobilised Cell Bio-Reactor Feasibility Study

## Introduction and Design Basis

Immobilised cell bioreactors are used to treat waste waters in a biological setting. The principle behind this technique is that biological organisms are ‘attached’ to a base, such as a solid particle, which immobilises them. These organisms then digest the waste either aerobically or an-aerobically, depending on the organism selected.

The basis of the design for this bioreactor consists of the composition of the wastewater and the flowrate.

From previous calculations the wastewater flowrate was determined to be 137271.25kg for a duration of 18 months with a crew of 10. This equates to a requirement of 250.72kg/day and includes both water for human consumption and hygiene, e.g. showers. It is assumed that non of this water is retained, and thus the flowrate of wastewater will be 250.72kg/day.

The composition of this wastewater is to be taken as the standard composition of domestic wastewater on Earth, which is.

|  |  |
| --- | --- |
| **Pollutant** | **Concentration** |
| **[]** | **[mg/Litre]** |
| Total Suspended Solids | 200-300 |
| BOD | 200-250 |
| COD | 350-450 |
| Nitrogen | 25-60 |
| Phosphorus | 5-10 |
| Oil and Grease | 80-120 |

Reference - http://www.unep.or.jp/ietc/publications/techpublications/techpub-15/3-9ilandcaribbean/9-1.asp

These are the waste compounds within the water that must be removed to produce potable water. For this feasibility study it was assumed that all water would be treated to a potable standard. It was also assumed that the oil and grease would be able to be digested by the same organisms that digest the BOD and COD. Taking the average values for BOD and COD gives a ratio of 1.77 COD to BOD. This shows that bacterial growth is not inhibited and thus biological removal is a possibility.

It would be possible to split the streams, as water used for hygiene purposes would not have to be treated to a potable level, which would reduce the size of plant required. However it could potentially require an additional unit, which would increase the complexity of the process.

Potable drinking water requirements are set

## Process Description

There are two possible configurations for and ICB setup for waste water treatment.

**Configuration 1 (from a life support systems paper)**

In this configuration, the waste water is treated to remove organic carbon compounds and ammonia first. Suspended solids are removed downstream of the process.

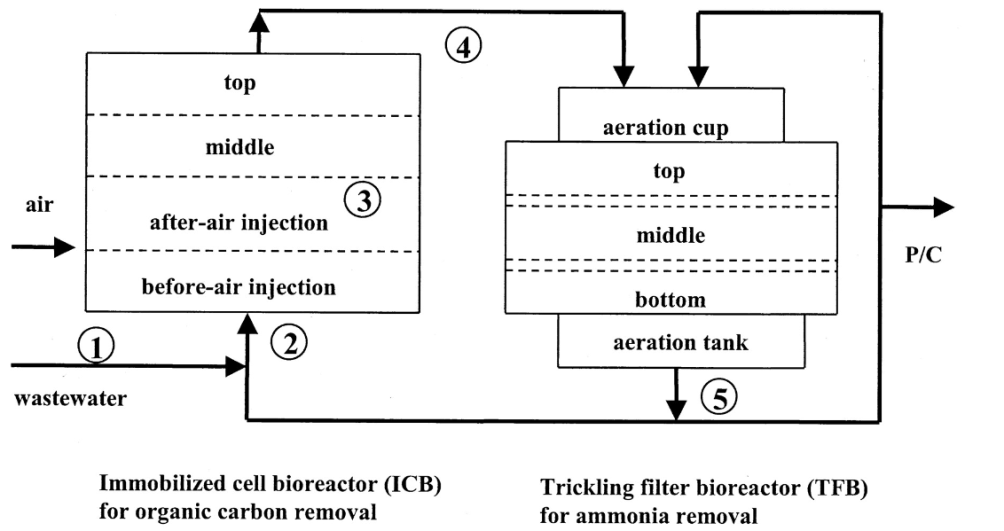
For this process the wastewater is first sent to an immobilised cell bioreactor which removes the organic carbon content of the waste. The organic carbon content is made up BOD and COD. The most commonly used immobilised reactors for treatment of waste water are packed bed, fluidised beds and CSTRs. Fluidised beds are the most effective through reductions in treatment times, reduced volume reactors and the lack of clogging of biomass[[1]](#footnote-1).

The wastewater is fed into this reactor, where a suitable organism will be immobilised upon solid particles. Air is fed into the reactor to provide oxygen for the aerobic digestion of the waste. Some nitrogen and phosphorus will also be removed from the water as these are consumed by the organism for growth. The effluent of this reactor will have lower concentrations of organic carbon compounds.

This reactor effluent is then fed into a Trickling Filter Bioreactor, where the concentration of ammonia in the wastewater is significantly reduced.

The TFB effluent is then split into two streams. One stream is recycled back into the process, to further reduce the concentrations of the reactor effluent stream. The second stream is then sent to further physicochemical reactors[[2]](#footnote-2). These are designed to remove suspended solids in the treated water[[3]](#footnote-3).

The BFD for this configuration is shown below.

[[4]](#footnote-4)

**Configuration 2 (modified paper design by me)**

An alternative approach is the remove the suspended solids upstream of the immobilised cell bioreactor. Assuming that the suspended solids are digestible, anaerobic digestion could be performed in an additional ICB. Anaerobic digestion is an ‘essential unit operation’ prior to an ICB to reduce the wastewater viscosity and remove colloidal solids[[5]](#footnote-5).

The untreated wastewater is fed into an anaerobic ICB. This will reduce the BOD, COD and suspended solids of the wastewater. As a by product ammonia and biogas will be produced. The main constituents of biogas are carbon dioxide and methane. These can be withdrawn from the water treatment process. The carbon dioxide can be utilised in the Sabatier process to produce methane and hydrogen. The methane in these reactions could be steam reformed, then shifted to produce CO2 and H2O as the main products. The CO2 could be recycled back into the Sabatier process and the H2O used directly as a source of water.

The anaerobically treated waste water will then be fed into the system shown in configuration 1. The first IBC will operate aerobically, and digest the organic carbon compounds, effectively reducing the COD and BOD of the water. The second reactor will remove the ammonia from the water. This water will be treated to low levels of all contaminants and should be potable.

A BFD for this process is shown below.

## 

## Equipment Specification (numbers)

For the first configuration, a study was undertaken for the reactor setup as shown. This achieved a removal of 94% and 48% for TOC and Ammonia respectively[[6]](#footnote-6).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TOC Removal | NH4 Removal | Feed Flow | ICB Volume | TFB Volume |
| [%] | [%] | [kg/day] | [m^3] | [m^3] |
| 94 | 48 | 110.6 | 0.11 | 0.07 |

The treated water was processed ‘in a series of physicochemical treatments and stored for human consumption’[[7]](#footnote-7).

Assuming that the physicochemical treatments only removed suspended solids, the results should also apply for the second configuration. If some of these suspended solids are not digestible, then an additional filter would be required to remove these from the water supply.

# Advantages and Disadvantages

**Overall Process**

In terms of the advantages and disadvantages of using bioreactors for treatment of wastewater on a mars space station...

**Advantages**

* Equipment is not complex. Therefore will have very little that can break down and thus machinery will have high reliability and long life cycle
* Can handle a wide variety of biodegradeable waste compounds
* Can produce methane as a potentially useful by-product

**Disadvantages**

* Reliant on living organisms for water supply
* Very temperature sensitive
* Organisms will have to be specific for the environment
* Can produce ‘sludge’ which could potentially be difficult to deal with
* Product water composition variable depending on the growth of organisms
* High recycle rate needed for potable concentrations, meaning a lot of water ‘in situ’ and thus inaccessible.

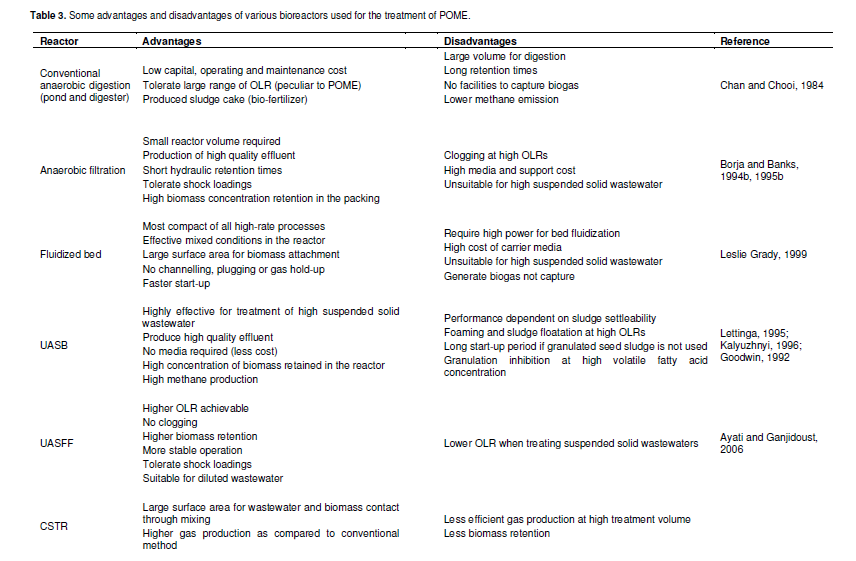
**Configuration 1**

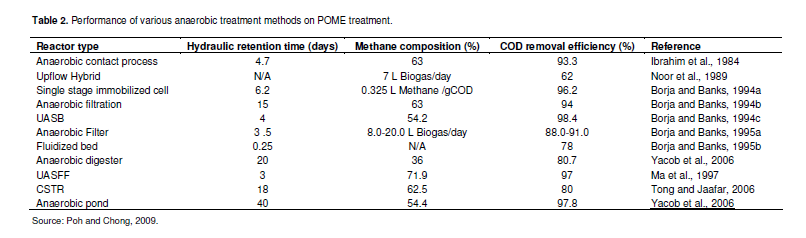
Not a clue.

**Configuration 2**

As the physicochemical methods used in configuration 1 remain unknown, it is assumed that they create no useful by product. In comparison the unit operations in configuration two produces methane as a by product. This could potentially be reformed into syn-gas using a steam reformer. Then this gas can manipulated using the shift reaction equilibrium to produce high quantities of both CO2 and H2O. The H2O can be added directly to the station water reserve, and the CO2 can be used in the Sabatier reaction for oxygen production. This allows additional recovery of the hydrogen from the waste compounds being removed from the wastewater.

There are many types of anaerobic reactors that can be used to achieve this. A comparison of these was made in a paper on palm oil effluent treatment. This has similar ratios of waste components to that of the domestic waste composition assumed in this report. The comparison undertaken is shown below.





The method that I would recommend is the anaerobic filtration. This removes the colloidal solids from the wastewater early on. These solids limit the effectiveness of the downstream ICB and TFB, hence by removing them early in the process we can increase the efficiency of the units downstream[[8]](#footnote-8). This will also remove the solids from the recycle, which for the TFB is very large.

Downstream of the anaerobic bioreactor, the configuration is the same as configuration 2 and so will have the same advantages and disadvantages,

## Conclusion

1. Comparative Study of Immobilized Cell Bioreactors for Industrial

   Wastewater Treatment [↑](#footnote-ref-1)
2. Spatial Distribution of Total Ammonia-Oxidizing and Denitrifying Bacteria in Biological Wastewater Treatment Reactors for Bioregenerative Life Support [↑](#footnote-ref-2)
3. http://iwawaterwiki.org/xwiki/bin/view/Articles/Physico-chemicalWaterTreatmentProcesses [↑](#footnote-ref-3)
4. Spatial Distribution of Total Ammonia-Oxidizing and Denitrifying Bacteria in Biological Wastewater Treatment Reactors for Bioregenerative Life Support [↑](#footnote-ref-4)
5. http://www.aiaaeration.com/news/index.php?entry=6 [↑](#footnote-ref-5)
6. Spatial Distribution of Total Ammonia-Oxidizing and Denitrifying Bacteria in Biological Wastewater Treatment Reactors for Bioregenerative Life Support [↑](#footnote-ref-6)
7. Spatial Distribution of Total Ammonia-Oxidizing and Denitrifying Bacteria in Biological Wastewater Treatment Reactors for Bioregenerative Life Support [↑](#footnote-ref-7)
8. Application of Semi Fluidised bed bioreactor as novel bioreactor system for the treatment of palm oil mill effluent [↑](#footnote-ref-8)